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The initial stages of growth of Ge on Si(001) studied by x-ray diffraction

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Abstract. The structure of an ultra-thin epitaxial Ge layer during *in situ* deposition onto a Si(001) surface has been investigated. Peaks arising from the 2 × 1 reconstruction disappear at a coverage of ≈3 ML. The layer is epitaxial with respect to the substrate up to a coverage of ≈5 ML, beyond which the strained layer relaxes gradually. At a coverage of 10 ML the lateral strain is reduced to 2.2% compared with 4.0% in the unrelaxed layer.

Epitaxial germanium layers may be grown on the Si(001) surface in a layer-by-layer mode up to a critical thickness of 6 ML [1]. Grazing-incidence x-ray diffraction at the Daresbury synchrotron has been used to investigate quantitatively strain relief and reconstruction during *in situ* deposition onto a clean Si(001) substrate at a temperature of 500 °C.

The (1.5, 0, 0.02) and (0, 1.5, 0.02) fractional-order peaks, arising from the double-domain 2 × 1 reconstruction, were monitored as a function of coverage θ. Their intensity was greater at $\theta = 1$ ML than for the clean surface, indicating that the reconstruction involves dimerisation of the heavier Ge atoms. The peak width was unchanged at both

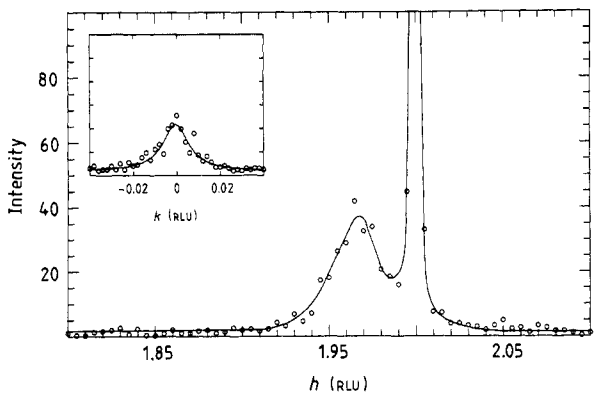

Figure 1. A radial scan through the (2, 0) Bragg peak for $\theta = 10$ ML. The inset shows a transverse scan at (1.965, 0).

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coverages corresponding to an average reconstructed domain size of 3800 Å. For θ = 2 ML and 3 ML the peak became much weaker and the domain size decreased to 2200 Å. The reconstruction was not observed at higher coverages, in agreement with LEED data [2].

Radial scans in reciprocal space through the (2, 0) Bragg peak, at the critical angle of incidence of 0.20° for which the penetration is ≈30 Å, were used to quantify strain relief. The peak from the Ge layer superimposed on that of the underlying Si up to θ = 5 ML. This indicates that the layer is epitaxial with the substrate, the lateral strain of (4.0 ± 0.4)% not being appreciably reduced. At θ = 7 ML the peak is shifted, the strain being (3.4 ± 0.4)%, and at θ = 10 ML the strain is (2.2 ± 0.3)% (figure 1). The Ge layer is thus not fully relaxed at this coverage. A transverse scan through the Ge peak displayed a Lorentzian profile, indicative of exponentially decaying correlations. The peak width corresponds to a correlation length of 85 Å (figure 1). If it is assumed that this peak is due to islands of Ge, which have been observed with SEM for θ = 20 ML [3], then average lateral dimensions of ≈200 Å are obtained.

References

[1] Bevk J, Mannaerts J P, Feldman L C, Davidson B A and Ourmazd A 1986 *Appl. Phys. Lett.* **49** 286–8
[2] Asai M, Ueba H and Tatsuyama C 1985 *J. Appl. Phys.* **58** 2577–83
[3] Ishimaru N, Ueba H and Tatsuyama C 1988 *Surf. Sci.* **193** 193–211